XVIII. *On the Nervous System of the* Sphinx ligustri, Linn., *and on the changes which it undergoes during a part of the Metamorphoses of the Insect. By* George Newport, *Esq. Communicated by* P. M. Roget, *M.D. Sec. R.S.*

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In this paper it is proposed to describe the development and arrangement of the nerves, and the changes which they undergo, in the *Sphinx ligustri*, Linn., during the last stage of the larva, and the earlier stages of the pupa state.

The labours of that industrious naturalist Heroldt have already shown us, to a certain extent, in what manner similar changes occur in the *Papilio brassicæ*, Linn.; and therefore the author of the present essay would not have ventured to trespass upon the attention of the Royal Society, were it not that these changes are capable of more minute explanation than those which take place with such rapidity in the *P. brassicæ*. But the *Sphinx ligustri*, Linn., remaining as it does for several months in an apparently torpid condition, between its larva and perfect state, allows us an opportunity of more deliberately observing in what manner the changes are effected; while the superior bulk of the insect enables us to trace them with greater precision.

The *Sphinx ligustri*, like other Lepidopterous insects, after coming from the egg, has three very distinct periods of existence, recognised as the larva, the pupa, and the perfect state. In the larva state there are also distinct periods, terminated by the change of skin which takes place at the expiration of each. This change of skin occurs six times before the insect passes into the pupa state. After each change the larva becomes much enlarged, feeds more voraciously than at any preceding period, and when arrived at the sixth and last, which is always of longer duration than the earlier ones, increases so rapidly in bulk as to become at least a third larger than at any earlier period. Its nervous system undergoes a corresponding development. In every stage it is composed of two longitudinal cords, united at certain distances by ganglia. Of these

there are now eleven, [Plate XII. fig. 1. (1, 2 to 11),] besides a nodulated mass in the head which is supposed to represent the brain, [fig. 1. (A), fig. 2. (A).] This mass lies above the œsophagus, and is formed of two lobules closely united, convex upon their upper, and a little concave on their under surface, so as in the middle line to accommodate themselves to the anterior part of the dorsal vessel, which passes immediately beneath them, and to the œsophagus along which this is directed. The longitudinal cords originate from the under surface of these lobules, [Plate XII. fig. 2. (G),] and passing a little backwards meet beneath the œsophagus, and, by their uniting, form the heart-shaped or first ganglion, [fig. 1. (1), fig. 2. (H, 1).] From this they are continued close to each other into the next segment, or true collar of the future moth, and here connected form the second ganglion, [fig. 1. (2),] which is nearly of a spherical form. The cords then gradually diverge, and proceed apart from each other, passing on the outside of, and inclosing between them the insertions of some of the diagonal muscles of the future thorax, until they again unite in a third and distinctly bilobate, heart-shaped ganglion, [fig. 1. (3).] From this they are continued in the same manner into the fourth segment, and uniting form a similarly-shaped fourth ganglion, [fig. 1. (4).] They then pass close to each other into the anterior part of the fifth segment, and form a ganglion, [fig. 1. (5),] the distance of which from the fourth, like that of the second from the first, is scarcely more than half of what exists between any of the other ganglia. From the fifth they are continued to the sixth, seventh, and so on to the eleventh segments, forming in the middle of each, one nearly spherical ganglion, [fig. 1. (5, 6, 7, 8, 9, 10, 11),] which has scarcely any appearance of having originally been formed of two lobes. The eleventh ganglion, however, is distinctly bilobate, [Plate XII. fig. 1. (11),] and at this period of the larva's existence is in reality a double ganglion, with a constriction in its middle, which is more or less apparent in different individuals; so that, as was suggested to me by Dr. R. E. GRANT, it is highly probable this eleventh, or terminal ganglion, consisted originally of two separate ganglia, with short intervening cords. This is the more probable as there are no ganglia, or cords, in the twelfth and anal segments, the parts being supplied with nerves directly from the terminal ganglion. This opinion is also supported by the fact, that in the larva of several other moths, particularly that of the *Phalœna* (*Bombyx*) *neustria*, LINN.,
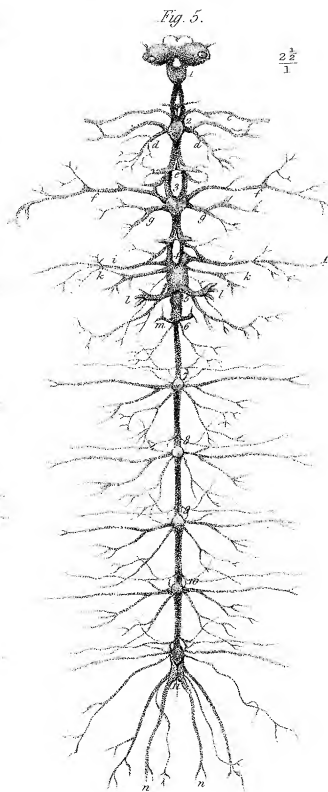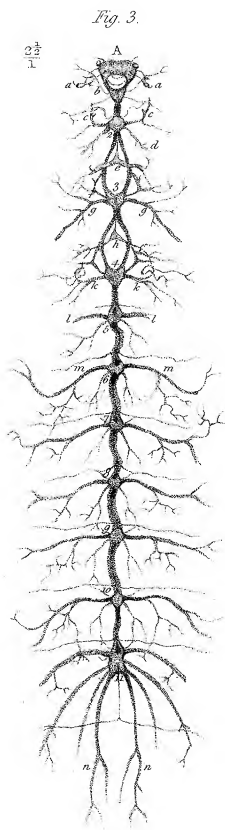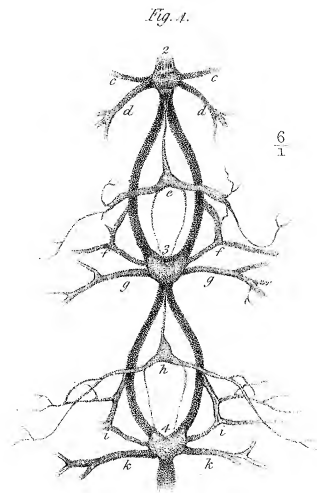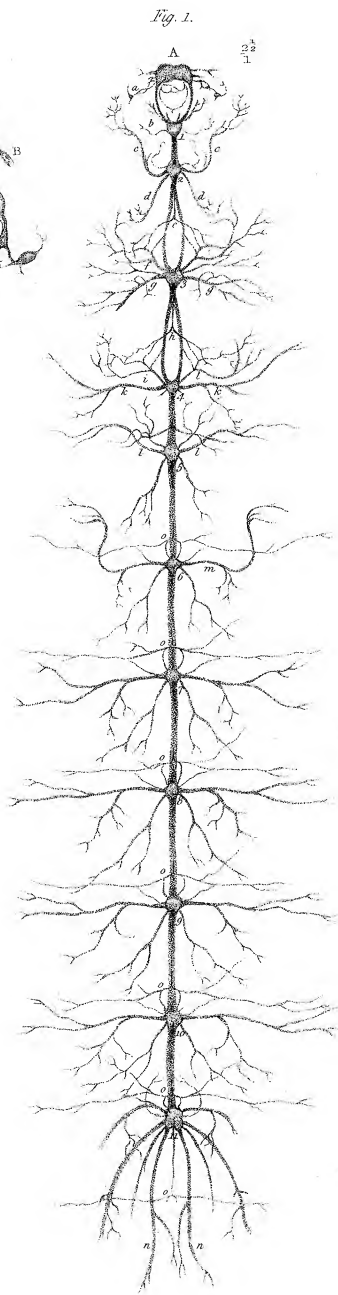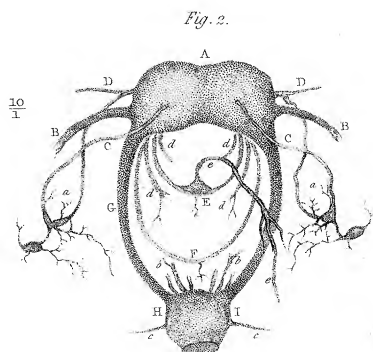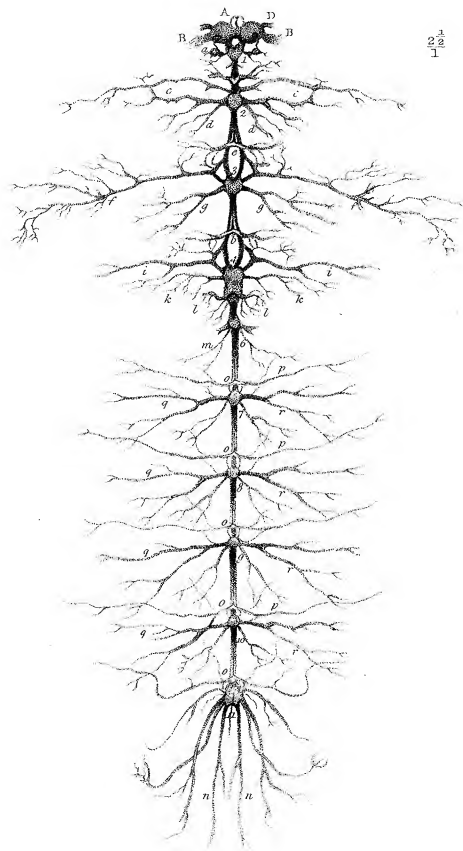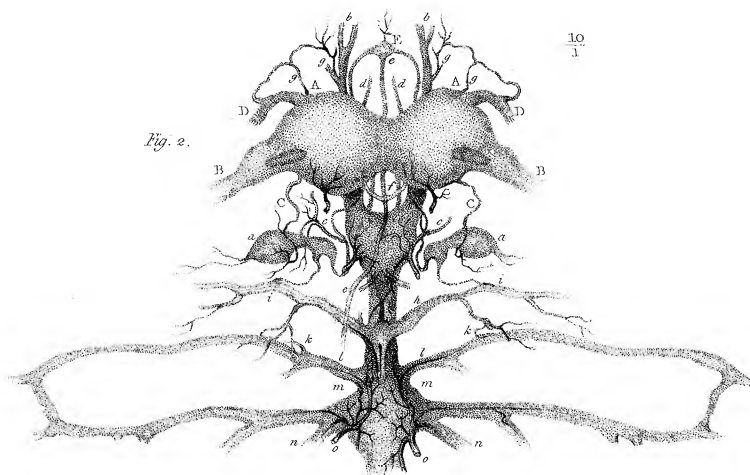
Fig. 2.

Fig. 1.

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Fig. 1.

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there are two very distinct ganglia, with intervening cords, which afterwards unite to form the terminal ganglion of the perfect insect.

In describing the nerves distributed from these ganglia, it may be well to consider them as belonging to the head, the thorax and abdomen. In the first there are the cerebral lobes and first ganglion, which are found in the head in every period of the insect's existence, but undergo a modification of form, are increased in diameter, and furnish nerves to the organs of sense and manducation. The second division comprehends the ganglia which furnish nerves to the true limbs, or organs of motion. These ganglia are contained in the second, third, fourth and fifth segments of the larva, which correspond to the collar and trunk of the pupa and perfect insect. The third or abdominal division comprises the ganglia in the eight last segments in the larva, and the corresponding ones in the pupa and perfect state. The cords in this division are much shortened, and the number of the ganglia diminished, during the change of the insect from the larva to the perfect state.

Nerves of the Head.—When viewed from above, the cerebral lobes are pretty uniform in appearance, and are clearly distinguished from each other by a depression between them. This is more apparent on the anterior than the posterior surface, and arises from the lateral part of each lobe being carried a little forwards, so that the two lie across the œsophagus in a curved or semilunar direction. From the anterior and lower part of each lobe originate four remarkable nerves. Two of these [Plate XII. fig. 2. (*d, d, d, d*)] are distributed towards the front of the head, near the flexor muscles of the mandibles; a third passes a little forwards, descends, and, uniting with its fellow from the opposite lobe, forms a circle [fig. 2. (F)] round the œsophagus, to the under surface of which it distributes a few filaments; while the fourth, which originates rather higher up than the others, forms what has been called by LYONNET the recurrent ganglion and nerve, [Pl. XII. fig. 2. (E); Pl. XIII. fig. 2. (E).] From its origin, this nerve is directed forwards and downwards, along the side of the œsophagus, or rather posterior part of the mouth, but gradually altering its course inclines upwards and inwards, and then a little backwards, until, by meeting its fellow of the opposite side above the roof of the mouth, the two by their union form a semilunar ganglion [Pl. XII. and XIII. fig. 2. (E)] immediately below the bifurcated portion and distribution of the dorsal vessel.

From the front, or most convex surface of this ganglion, originates a small branch that distributes filaments in the direction of the superior lip ; while a large nerve is produced from the posterior surface, [fig. 2. (e, e),] which passes backwards beneath the cerebral lobes, along the middle of the œsophagus, covered by the dorsal vessel. On arriving at the stomach, it divides into three branches, [Pl. XII. fig. 2. (E, e); Pl. XIII. fig. 2,] which are distributed chiefly to that organ. Throughout the whole of its course, from the ganglion to this division into branches, it distributes filaments to the dorsal vessel and to the œsophagus. I have not yet succeeded in tracing it in this insect beyond the anterior part of the stomach, but in the *Gryllus viridissimus*, LINN., I was once enabled to follow its central division along the whole of the stomach, and part of the small intestine, from which, with a little care, it was readily detached. Its length from the ganglion to the trifid division in the Sphinx, is much increased during the changes of the insect, and corresponds precisely with the elongation that takes place in the œsophagus. The form of the ganglion undergoes no alteration. From the analogy that exists in the distribution of this nerve to that of the eighth pair in the vertebrated animals, it is probable that its functions are of a somewhat similar nature,—that in reality it is the par vagum, or pneumogastric nerve of insects. In fact, this is the pretty generally received opinion respecting it, and is clearly that of STRAUS DURCKHEIM, who describes it in his Anatomy of the *Melolontha vulgaris*. It must be confessed, however, that there are objections to such an opinion, since it is not yet proved to distribute any filaments to the respiratory organs, although it can hardly be doubted that such distribution does really exist, when we remember the abundance of tracheal vessels which ramify upon the stomach, and with which its filaments must necessarily come in contact. The other nerves from the cerebral lobes arise nearer the lateral surfaces. The first of these are destined for the future antennæ, and proceed from the front, near the origin of the cords, [Pl. XII. and XIII. fig. 2. (D).] At the last period of the larva state they are of considerable size and length, and lie packed in sigmoid folds on each side the head, within the cranium. The next are the optic nerves. These come from the upper part of each lobe, [Pl. XII. and XIII. fig. 2. (B),] and in the larva are scarcely more than slender cords directed diagonally outwards to the six minute eyes. In addition to these nerves from the

cerebral lobes there are also two minute pairs which form very remarkable ganglia, similar to those described by STRAUS DURCKHEIM in his Anatomy of the Melolontha. These ganglia I have ventured to call anterior lateral ganglia. The two pairs of nerves originate, one from the base of the nerve to the antennæ, the other from the posterior surface of each lobe, [Pl. XII. and XIII. fig. 2. (a, c).] They are directed backwards and outwards, and after passing for some distance unite and form an irregular lunated ganglion, which is closely connected to another of an oval form. Both these ganglia distribute filaments to the muscles of the neck and to a lateral branch of the dorsal vessel, and are connected with a system of nerves derived from the large ganglion in the second segment, [Pl. XIII. fig. 2. (a, c, i).]

All the nerves which supply the organs of motion belonging to the head and mouth, excepting only those to the antennæ, derive their origin from the first ganglion. There are four distinct pairs; three of which proceed from the anterior, and one from the lateral surface of the ganglion. The largest pair from the anterior surface are divided into three branches, and go directly to the mandibles [Plate XIII. fig. 2, (b, b)] ; the next to the palpiform spinnerets [fig. 2. (d, d)] ; and the third apparently to the inferior lip; while the lateral pair [fig. 2. (c, c)] are given exclusively to the silk-bags, which afterwards are the salivary vessels of the perfect insect.

Nerves of the Thorax.—These arise from the second, third, fourth and fifth ganglia, and their intervening cords, [Plate XII. and XIII. fig. 1. (2, 3, 4, 5).] The first pair from the second ganglion are remarkably small in the larva, and their distribution is not easily traced. The second are large, directed forwards, and divided into many branches, which supply the muscles of the head and neck, [fig. 1. (c, c).] The third are carried backwards for a little distance, and then turning forwards enter the first pair of legs, [fig. 1. (d, d).] Both the cords between the second and third ganglia produce a single nerve, which is directed backwards, and unites at an angle with the first nerve from the third ganglion, [fig. 1. (f, f).] These form a single trunk, which goes to the first pair of wings in the perfect insect. It is now of small diameter, but is carried forwards and distributes filaments among the muscles at the anterior part of the segment. This trunk is also connected with a system of nerves of which we shall speak more particularly hereafter. The second pair from the

third ganglion, [Plate XII. fig. 1. (3, *g*, *g*),] distribute from their base a small branch, which looks like a distinct nerve, while their main trunks, at a distance from the ganglion, divide into two branches, and are given to the second pair of legs. The cords between the third and fourth ganglia produce also a nerve that unites, in a manner similar to the preceding, with the first nerve from the fourth ganglion, [fig. 1. (4, *i*, *i*),] and forms a trunk which ramifies among the muscles of the fourth segment, and is destined for the second pair of wings. The second pair of nerves from the fourth ganglion [fig. 1. (4, *k*, *k*),] are given to the third pair of legs. The nerves from the fifth ganglion [fig. 1. (5, *l*, *l*)] belong also to the thorax, and are those which are given to the muscles of the hinder part of the thorax in the perfect insect.

Nerves of the Abdomen.—All the nerves from the sixth to the terminal or eleventh ganglion, belong to this division, and, with the exception of those from the latter, are pretty nearly uniform both in number and distribution. Each ganglion produces one pair of small nerves, and one of large. The small ones are given to the fat and minute tracheæ of the ventral surface. The large ones pass transversely across the segments, and divide each into two branches. One of these [Plate XIII. fig. 1. (*q*, *q*, *q*, *q*)] passes over the inner range of fibres and between the layers of abdominal muscles, and following the course of the trachea gives its branches to the dorsal muscles, and to the integuments of the back ; while the second, [fig. 1. (*r*, *r*, *r*, *r*),] passing also between the layers of ventral muscles, distributes its branches to their inner surface, and to the integuments of the under surface of the body. The eleventh or terminal ganglion [Plate XII. fig. 1. (11)] produces five pairs of nerves, four of which are of considerable size. These are arched backwards, and three of them are given to the remaining segments of the body, while the others supply the colon, rectum, and rudiments of the organs of generation.

Besides the nerves thus described, as constituting those of the head, thorax and abdomen, there are others which merit some attention, as they seem to form a distinct or superadded series. LYONNET has accurately delineated them in his excellent Anatomy of the larva of the Cossus. There is a plexus of them lying transversely in every segment, attached by apparently a single filament, passing between the longitudinal cords to the posterior part of every ganglion, [Plate XII. and XIII. fig. 1. (*e*, *h*, *o*, *o*, *o*, *o*, *o*).] Some of the

nerves from each plexus in the abdomen unite with the principal nerve from the next ganglion [Plate XIII. fig. 1. (q, q, q, q)], while others ascend and ramify among the tracheæ and dorsal muscles. The principal branch [fig. 1. (p, p, p, p)] goes directly to the tracheæ which come from the spiracula. In the thorax, the plexus from the hinder part of the second ganglion, [Plate XII. and XIII. fig. 1. (2, e),] unites some of its filaments with the nerve destined for the first pair of wings, while others are distributed among the muscles. The nerves from the plexus attached to the third ganglion give, in a similar manner, some of their filaments to the nerve intended for the second pair of wings, and some to the muscles. The second ganglion has the transverse plexus from the first, attached pretty closely to its anterior surface. This plexus distributes its nerves laterally to the muscles of the head and neck. It is also united by a small branch with the anterior lateral ganglia, [Plate XIII. fig. 2. (a, i),] and with the first pair of nerves from the second ganglion, [fig. 2. (k, k, l, l),] so as to form a complete link or medium of communication between the nerves and ganglia of the head, neck, and second segment. From this it seems probable that these nerves may constitute the origin of a distinct system ; but whether this system in insects be analogous, either to the sympathetic or to the respiratory system of vertebrated animals, is yet a matter of inquiry. From the principal branches from each abdominal plexus being always distributed among the tracheæ, near the spiracula, there seems reason for inclining to the latter opinion.

Such is the arrangement of the nervous system when the larva has attained its full growth, and ceased to eat, preparatory to its changing into a pupa. This generally takes place at about the middle of August, or in the beginning of September. Some individuals undergo the change three weeks or a month earlier than others, owing to their having been developed from the egg at an earlier period; and the length of time they continue in the state of larva is about seven or eight weeks. The first symptoms of the insect being about to change to the pupa state occurs in its ceasing to eat, and after having remained quiet for a few hours, becoming exceedingly restless, and moving about with great rapidity. It then enters the earth, and forms an oval cell lined with a thin silky coating, and in it awaits its change. The delicate pea-green skin of the larva now becomes of a rusty orange colour, is shrivelled

and contracted, and is often covered with moisture. At this period all the nerves belonging to the ganglia of the first five segments are directed forwards, [Plate XII. fig. 1.,] while the lateral nerves from the ganglia in the posterior segments are disposed with some irregularity. If the larva be prevented from undergoing its metamorphosis, by having been removed from its cell in the earth, and also prevented from remaining at rest, the nervous system is but little altered. But the change can be retarded only for two or three days, when the insect, upon being allowed to remain at rest for a short period, entirely loses the power of locomotion, becomes much shortened and contracted, and in its general appearance resembles the future pupa. When the period of change has arrived, the larva forces an opening through its skin, along the dorsal part of the third and fourth segments, and by repeated efforts continues it forwards as far as the head, the covering of which separates into three pieces. The head and trunk of the new pupa, with all their parts separate, but encased each in a very delicate skin, and nearly as fluid as water, are then gradually withdrawn from beneath the old covering, and disposed along the under surface of the body, while the skin itself, by repeated contractions of the abdomen, is forced up together, and entirely slipped off at the anal segment. The new pupa then lies at rest, and the coverings of its limbs and body adhere together and form a hard case, capable of preserving it from injury. During this, its nervous system is also changing, by the cerebral lobes being increased in size, and the eleven ganglia brought nearer together, by the shortening which is taking place in their respective segments, so that the longitudinal cords lie in a very irregular manner between the ganglia, while the ganglia themselves are confined in their proper places in the segments by the nerves running transversely from them.

If the insect be examined about two hours previously to its bursting the exuviæ and becoming a pupa, the change in its nervous system is very evident, [Plate XII. fig. 3.] The lobes above the œsophagus have assumed more the appearance of a cerebral mass, [fig. 3. (A),] and are increased in diameter, while the cords descending from them are shortened and thickened. The nerves for the antennæ are enlarged, and lie folded on each side the head, and the optic nerves have undergone considerable alteration. Instead of being simple cords, they are now so much shortened and thickened, as to be hardly distinguish-

able from the lobes themselves, upon the upper part of which they are situated, while an ovate patch of a purplish substance is observed upon their surface. This has existed in every specimen I have dissected, and seems to form part of what is to become the dark pigment for the eye of the future moth. The ganglion that produces the nerve to the œsophagus and stomach has undergone no alteration, nor have the anterior lateral ganglia, [Plate XII. fig. 3. (a, a),] and there is still a loop or nervous ring around the anterior part of the œsophagus, as in the perfect larva. There are still eleven ganglia [fig. 3. (1 to 11)] upon the longitudinal cords; but none of these are yet increased in size, nor is there any particular alteration in the distribution of the nerves from the six abdominal ones, while the cords are still disposed in an irregular manner, and have not increased in diameter. But in the thorax the nerves are much enlarged, particularly those sent to the wings, while in some instances the nerves belonging to the posterior pair of legs are curiously convoluted within the thorax, preparatory to their being unrolled at the instant of the change to the pupa, [fig. 3. (4, k).] The superadded or transverse plexus of nerves are also enlarged, particularly at the points of union with the filaments which connect the plexus with the ganglia. They are occasionally so much increased at those points as to form distinct but irregularly shaped ganglia, nearly one third the size of the longitudinal ones of the cord, [Plate XII. fig. 4. (e, h).] The lateral branches of the plexus have sometimes minute ganglia, [fig. 4. (e),] from which the nerves are produced; but this is not often the case.

Four days after the insect has become a pupa, the nervous system is much in the same state as at the moment of transformation, the chief difference being in the fifth ganglion having advanced nearer to the fourth, and become more indistinct, while the diameter of the cords has increased, so as to equal the whole diameter of the ganglion. The cerebral lobes, optic nerves, and anterior lateral ganglia, as well as the ganglia of the trunk and abdomen, continue nearly in the same state as before, and the cords, although a little shortened, are still irregularly disposed in the abdomen.

Thirty days after the change there is a considerable alteration in the nervous system, [Pl. XII. fig. 5.] The cerebral lobes are more increased, the optic nerves a little extended, and the first ganglion has been brought so very close to the lobes as to appear to constitute with them a single mass, through which

there is a small aperture for the passage of the œsophagus. All the ganglia of the thorax are much enlarged, and the first pair of nerves which belonged to the second ganglion in the larva, now appear to take their origin from the cords, [fig. 5. (2, *c*),] and after anastomosing with the second pair, to form with them a plexus which supplies the neck and collar ; while the third pair pass as before to the muscles of the first pair of legs, [Pl. XII. fig. 5. (2, *d*).] The first pair from the third ganglion, and the roots they derive from the cords, are much enlarged, [fig. 5. (3, *f*),] as also are the second pair given to the second pair of legs. But the greatest alteration is in the fourth ganglion, [fig. 5. (4),] which is now more than double its former size, is elongated and bilobate, and gives off four pairs of nerves. The first, with the roots they derive also from the cord, are given to the inferior wings ; the second, to the third pair of legs ; the third pass backwards to the muscles of the abdomen ; and the fourth are directed upwards, divided into three branches, and are distributed to the posterior muscles of the trunk. The fifth ganglion is close to the fourth, [fig. 5. (5),] and coalesces with it ; the nerves last described being those which originally belonged to it. The sixth ganglion, [fig. 5. (6),] much decreased in size, is often found at this period close to the fifth, from which it is separated only by a slight indentation. It is more frequently, however, at a short distance from it. The longitudinal cords are no longer irregularly folded in the abdomen ; they now lie in a direct line between the ganglia, [fig. 5. (7, 8, 9, 10, 11)] ; but neither these nor the cord itself are increased in diameter.

It is thus evident that the principal part of the change in the nervous system of this insect occurs during the first month of the pupa state, and that it is not regularly progressive, but takes place at intervals. Upon what these apparent irregularities depend it is difficult to determine. Perhaps they may be the result of a partial exhaustion of the vital powers, during the effort of transformation, and which require an interval of repose to re-establish their activity. Thus we find, that during the first four days of the pupa state, there is but little alteration of structure, beyond what exists at the actual period of changing from the larva ; the energy of the insect having been partially exhausted during the effort of transformation. But when it has remained for some time at rest, its energy is restored, and the change again advances. That such is in reality the case seems to be supported by the fact, that when a larva has become so ex-

hausted as to be unable to rid itself of the exuviæ, and complete its transformation, owing to its having been prevented from remaining at rest during the proper period, the change in its nervous system is never so much advanced as in those which have transformed without interruption ; nor does it make any further progress even in seven days, while the insect itself generally perishes in less than a fortnight.

After the insect has remained for about five weeks in the pupa state, scarcely any further change occurs in its nervous system until the following spring. This period of repose, during which the insect remains nearly torpid in its cell in the earth, continues for at least twenty-three or twenty-four weeks, and extends in general from the middle of October to the beginning of the following March, when, if the season be temperate, the change again advances. If the pupa be examined at any time during this interval, scarcely any alteration is observed in its nervous system, except an enlargement of the anterior lateral ganglia.

In the beginning or middle of March, when the pupa is becoming more lively, a change in the nervous system is evidently in progress. The cerebral lobes, [Pl. XIII. fig. 1. & 2. (A, A),] when viewed from above, are distinct from each other, are increased in size, and are of an irregular spherical figure. The ganglion called the recurrent, [fig. 2. (E),] rests immediately above a semi-cartilaginous arch, that forms the upper part of the mouth, while its nerve passes backward as before, distributing its filaments to the œsophagus, and anterior part of the dorsal vessel. The nerves to the antennæ are still in the same state as before, but a small branch [fig. 2. (D, ƒ)] may now be observed coming from their base, and directed downwards towards the mouth, and apparently connecting itself with the filaments from the nerves which belonged to the mandibles, and also to one from the anterior lateral ganglia, [fig. 2. (g).] The optic nerves are extending, and are greatly enlarged at their base, [fig. (B, B),] but there is no enlargement of the patch of dark pigment, [fig. 2. (B, c).] The nervous circle still exists around the anterior of the œsophagus, [fig. 2. (F),] and the anterior lateral ganglia are greatly increased in size, and still originate in the same manner as in the larva. But the nerves they distribute, and the connexions they form with other nerves, are more easily detected at this than at an earlier period. The first one, the lunated

ganglion, [fig. 2. (c),] distributes several minute nerves, one of which from its inner angle passes backwards, and is connected with the plexus of transverse nerves from the first ganglion of the trunk, from which plexus there are also filaments that unite with the first pair of nerves from the same ganglion, and thus establish a direct communication with the cerebral lobes. The other ganglion, the oval one, [fig. 2. (a),] is larger than the lunated, and distributes several branches. The distribution of nerves from the ganglia of the trunk and abdomen remains nearly the same. The transverse plexus have a little increased in size, and their union with the transverse nerves of the cord takes place a little nearer the ganglia.

I have thus described the structure and arrangement of the nervous system in the larva of the Sphinx, and the development which it undergoes during the earlier stages of the pupa state. In a subsequent paper, which I hope to have the honour of laying before the Society, these changes will be followed through the remaining stages, and some observations submitted upon the manner in which they are effected.

May 22, 1832.

Description of the Plates.

PLATE XII.

Fig. 1.—Nervous system of the larva of *Sphinx ligustri,* after it has acquired its full growth, and about two days previously to its change to the pupa state. Magnified two diameters and a half.

A. The supposed brain or anterior nodules of the cord.

1. The first ganglion situated in the head, or first segment beneath the nodules.

2, 3, 4, 5. Ganglia of the trunk supplying nerves to the legs and wings.

6, 7, 8, 9, 10, 11. Ganglia of the abdomen.

a. The anterior lateral ganglia. *b.* Nerves to the mandibles. *c.* Second pair from the second ganglion given to the muscles of the neck. *d.* Third pair given to the first pair of legs. *e.* The plexus of transverse or superadded nerves from the second ganglion. *f.* Nerves to the first pair of wings, originating from two roots, one from the cord and one from the third ganglion, and connected also with the transverse plexus. *g.* Second pair of nerves from the third ganglion given to the second pair of legs. *h.* Transverse plexus from the third ganglion. *i.* Nerves to the second pair of wings originating like the first, from two roots, one from the cord and one from the fourth ganglion, and connected also with branches from the transverse plexus from the third. *k.* Second pair from the fourth ganglion given to the third pair of legs. *l.* Nerves from the fifth ganglion, which, in the pupa, are those given to the posterior muscles of the trunk. *m.* Nerves from the sixth ganglion, which, in the pupa, are those of the anterior muscles of the abdomen. *n.* The last pair of nerves from the terminal ganglion given to the rectum and organs of generation.

Fig. 2.—The anterior lobes or brain, with the first ganglion and nerves of the head. Magnified ten diameters.

A. The lobes. B. The optic nerves. C. The nerves of the anterior lateral ganglia, one attached to the posterior surface of the lobes, the other to the base of those to the antennæ. D. Nerves for the antennæ. E. The singular nerve which has hitherto been called the recurrent, but which

appears analogous to the par vagum or pneumogastric nerve. F. The nervous circle formed by the union of two nerves that originate near the preceding, and surround the pharyngeal or anterior portion of the œsophagus, to the under parts of which they distribute a few filaments. G. The crura or cords which descend on each side the œsophagus and connect the superior lobes with the first ganglion. H. The first ganglion. *a.* The anterior lateral ganglia. *b.* Mandibular nerves. *c.* The lateral nerves of the first ganglion given to the salivary vessels or silk-bags.

Fig. 3.—Nervous system of *Sphinx ligustri* as found at about two hours previous to its change to the pupa state. Magnified two diameters and a half.

2, 3, 4, 5. Nerves of the trunk. 6 to 11. Nerves of the abdomen. The letters indicate the same parts as those in the larva in the preceding figures.

Fig. 4.—Nerves and ganglia of the trunk, exhibiting more clearly the form of the latter, and the gangliform appearance of the transverse plexus. Magnified six diameters.

2, 3, 4. The second, third, and fourth ganglia. The letters correspond with those of the preceding figures.

Fig. 5.—Nervous system of *Sphinx ligustri* thirty days after changing to the pupa state. Magnified two diameters and a half.

This drawing exhibits the abdominal cords in their shortened state, with only five instead of seven ganglia, the fifth and sixth having passed onwards and become continuous with the fourth. The cords in the trunk and the nerves to the wings are enlarged; and those nerves which were, in the larva, the first pair of the second ganglion, are also enlarged, and now originate from the cords, while the first ganglion has advanced very near to the superior lobes or brain. The terminal ganglion exhibits a very peculiar structure. The letters refer as before.

PLATE XIII.

Fig. 1.—The nervous system of *Sphinx ligustri* as found in the pupa about the middle of March, when beginning to revive from its previous torpidity. Magnified two diameters and a half.

A. The cerebral nodules. B. The optic nerves. D. Nerves to the antennæ. 1. The first ganglion. 2, 3, 4, 5. Ganglia and nerves of the trunk. 6 to 11. Abdominal ganglia.

a. Anterior lateral ganglia. *c.* The remarkable anastomosis of the nerves which were originally the first and second pairs of the second ganglion in the larva, the first of which now arise from the cords. They supply the muscles of the collar, or true thorax of the pupa. *d.* The last pair from the second ganglion given to the first pair of legs. *e.* Posterior plexus of the transverse nerves from the second ganglion. *f.* Nerves to the first pair of wings, originating as before from the cord and ganglion, and given to the muscles of the wings in the anterior part of the trunk. *g.* Nerves of the second pair of legs. *h.* Plexus from the third ganglion. *i.* Nerves to the second pair of wings, originating and anastomosing as before. *k.* Second pair of nerves from the large or fourth ganglion, given to the third pair of legs. *l.* Nerves which originally belonged to the fifth ganglion in the larva, and which are now the posterior nerves of the trunk. *m.* Nerves from the sixth ganglion given to the anterior muscles of the abdomen. *n.* Last pair of nerves from the terminal ganglion. *o, o, o, o, o.* Transverse plexus of the abdominal ganglia, much larger than in the larva. *p, p, p, p, p.* Those branches which ramify among the dorsal muscles and tracheæ, but chiefly the latter. *q, q, q, q, q.* The superior branches of the transverse nerves from the abdominal ganglia, which, after uniting with a branch from the transverse plexus, pass upwards to the dorsal muscles. *r, r, r, r, r.* The inferior branches from the same, given to the layer of ventral muscles and inferior tracheæ.

Fig. 2.—The ganglia and nerves of the head and collar, or true thorax of the pupa, as existing in the month of March. Magnified ten diameters.

In this figure the parts are represented in situ as seen when viewed from above.

A, A. The cerebral lobes. B, B. The optic nerves, considerably enlarged at their base, where there is deposited upon the upper surface, and partly upon the lobes, the patch of dark pigment. C, C. The nerve, which attached at the base of the antennal nerve connects it with the largest of the anterior lateral ganglia, while the other, the lunated one, is attached by a

filament to the posterior surface of the cerebral lobes, near where they are united. D. Nerves to the antennæ. E. The ganglion formed above the mouth by two nerves from the lower part of the front of the lobes, and which gives its nerve *e* along the œsophagus to the stomach, and which has been called the recurrent nerve.

a. Anterior lateral ganglia. *b.* The mandibular nerves which are now given to the tongue. *c.* Lateral nerves from the first ganglion, given to the salivary organs or silk-bags of the larva. *d, d.* Nerves from the front of the first ganglion, given to the inferior surface of the cavity of the mouth, into the substance of which they enter. They seem to be those which, in the larva, supplied the spinneret or excretory of the silk-bags. *e.* The nerve to the stomach. *f.* The nervous circle arising from the part of the lobes near the recurrent nerves, and, as in the previous state of the insect, encircling the pharyngeal portion of the œsophagus, at the hinder part of the mouth. *g, g.* Small nerves from the base of the antennæ passing downwards and uniting with a branch from the trigeminal or true mandibular nerves, and also with the nerve from the anterior lateral ganglia. *h.* Anterior plexus of transverse nerves from the second ganglion. *i.* A nerve connecting the plexus with the anterior lateral ganglia. *k, k.* Nerves connecting the plexus with the first pair from the second ganglion. *l, m.* Nerves which anastomose and supply the muscles of the collar. *n.* Nerves to the first pair of legs. *o.* Branches of tracheal vessels ramifying over the surface and entering into the substance of the nerves and ganglia.